6 Task force reports

Advanced Manufacturing and Material Engineering Task Force

In addition to being deployed as base-load power in large, centralized grids, nuclear power plants are increasingly likely to complement variable energy sources in distributed, localized and sometime remote grids. For nuclear energy to compete in this new paradigm, the industry must now focus on certain key characteristics. For example, designs with built-in, enhanced safety features and designs that focus on lower upfront capital costs, as well as those with shorter construction schedules, would allow nuclear power to obtain the social license required to operate and compete on the basis of overnight capital costs, and not simply based on the levelized cost of energy (LCOE). In addition, attributes such as non-electric applications (e.g. district heating, industrial process heat, clean hydrogen and synthetic fuels) and flexibility (e.g. load following) must now be considered for nuclear energy in these emerging, low-carbon energy systems.

Generation IV reactors are particularly suited to these requirements, and the last decade has seen a substantial rise in the number of active Gen-IV reactor designers and vendors worldwide. They typically involve:

- smaller, scalable designs, both in terms of size and output;
- simpler and compact modular designs that allow factory assembly and easier transport to construction sites;
- designs that focus on lower upfront capital costs and shorter construction schedules;
- designs with built-in enhanced safety features (passive/inherently safe designs);
- standardized designs to support volume production levels and a fleet approach to deployment;
- higher outlet temperatures and steam production for industrial applications (e.g. hydrogen production, water desalination, district heating, mining and resource extraction);
- designs with load-following flexibility to enable deployment in smart grids and hybrid energy systems.

Innovation in the nuclear supply chain, particularly in the areas of advanced manufacturing and materials engineering, is necessary if these advanced reactor technologies are to be delivered on time and on budget. However, nuclear design codes typically dictate that only qualified materials and processes can be used. Getting new materials or new manufacturing processes qualified can be a long and tortuous process. Furthermore, current developments in advanced manufacturing are occurring much faster than the ability of most to introduce new materials and methods into design codes, potentially stifling innovation and hampering deployment. These issues need to be addressed if advanced reactors, integrating innovative materials and components, are to be brought to the market in reasonable time frames.

The GIF Advanced Manufacturing and Materials Engineering Task Force (AMME TF) was therefore formed in order to better characterize and address these issues. As an initial step, the task force undertook a survey investigating the status of advanced manufacturing for nuclear reactor development and construction. The main outcomes of the survey can be summarized as follows:

- most advanced manufacturing methods were considered opportunities by potential end users;
- the techniques identified as having the greatest potential were cladding and surface modification techniques, welding and joining, and additive manufacturing;
- a total of 90% of respondents identified the greatest obstacle to adoption as being the approval of codes and standards organizations.

The survey also highlighted the evidence for strong support in collaborating at the international level on:

- establishing codes and achieving regulatory acceptance;
- organizing joint workshops as a means to design, initiate and promote joint activities;
- collaborating on materials and component/structural performance assessments to enable regulatory acceptance.

A well-attended Advanced Manufacturing Workshop was held at the Nuclear Energy Agency in Paris in conjunction with the R&D Infrastructure Task Force (RDTF) meeting on 18-20 February 2020. The purpose of the workshop was to identify both areas and methods where collaboration could lead to a reduction in the time to deployment of advanced manufacturing for advanced reactors. Workshop participants, from reactor vendors, nuclear supply chain firms, regulators, national laboratories and R&D providers enabled broad representation from across the nuclear industry, and the cross-functional breakout sessions were particularly engaging and successful. The output from the six breakout groups was discussed in the final session of the workshop, and final conclusions

were established. The overall recommendation of the workshop was that collaborative activities should be actively encouraged in three main areas:

- Qualification
  - codes and standards development;
  - a new qualification modality (e.g. real time process qualification);
  - an increased need for component testing.
- Demonstration and deployment
  - materials property database structure and content;
  - specific component testing;
  - round robin activity, e.g. generic intermediate heat exchanger (IHX) component.
- Design and modelling
  - collect experience and experimental data (feed data-driven methods);
  - share practices for inspection and design optimization;
  - resolve modelling and simulation benchmark problems.

There was strong support from the community for the AMME TF to continue its effort and organize follow-up workshops in due course. The future direction of the task force was discussed at the 43rd Experts Group and 49th Policy Group meetings. The AMME TF was encouraged to further develop its terms of reference (TOR), consistent with the workshop's recommendations.

Although progress in 2020 was affected by COVID-19, new TOR were drafted to refine the task force's objectives, define a new task force structure and provide action plans for the next 24 months. Following the 44th Experts Group and 50th Policy Group meetings, the reviewed TOR were approved in late 2020. Consequently, the task force will expand its activities and membership, and will conduct its activities through the three sub-working groups described below.

Requirements Capture Sub-Work Group

A key outcome of the February 2020 Advanced Manufacturing Workshop was the requirement to communicate and consult with the wider community to ensure the task force's success. The initial AMME TF survey was very successful in both identifying the needs of the community and raising awareness of the activities of the task force. These tools for requirements capture will thus be regularly used to update the task forces aims and outcomes. Community engagement will be pursued through regular targeted surveys enabling the task force to monitor stakeholder requirements, provide opportunities for stakeholder involvement and report progress on its activities. The next AMME TF survey is scheduled for 2021.

Qualification, Demonstration and Deployment Sub-Work Group

New approaches and methods for qualification of manufacturing processes, materials or components are key to the timely deployment of advanced manufacturing methods and materials. Although different AMME technologies may require different approaches, there are likely to be commonalities. Therefore, the first focus of the working group will be to identify these commonalities by sharing experience across different reactor systems, AMME technologies and national qualification approaches. The second focus of this working group is to elaborate on the qualification of specific components/materials or processes by studying their real or projected demonstration and deployment. As a final goal, a roadmap and guidelines for the development and implementation of qualified nuclear advanced manufacturing will be developed.

Design and Modelling Sub-Work Group

The February 2020 workshop underlined the need to capture and share processes and methodologies for ensuring product quality, and more specifically to: 1) collect experience; 2) share practices for inspection and design optimization, and 3) develop modelling and simulation benchmarks. This working group will consider three different categories of modelling: software and modelling assisted design, best practices for inspection and design optimization and organization of modelling and simulation benchmarks. In addition to requirements and the efficient use of modelling into materials and component accelerated development, qualification process has also been identified in the roadmap to meet these requirements.

Lyndon Edwards
Chair of the AMME TF, with contributions from AMME members

Research and Development Infrastructure Task Force

R&D infrastructure

Today's research infrastructure needs, from R&D to demonstration and deployment, cover major scientific equipment, scientific collections, structured information, information and communications technology (ICT)-based infrastructures. These facilities are single-sited or distributed throughout several countries. GIF member countries are faced with a wide spectrum of issues related to infrastructure, many of which are globally unique and regionally distributed. A great deal of stakeholders are involved, from ministries to researchers and industry, with an underlying and growing use of e-infrastructure. Research infrastructures present opportunities for, and yet difficulties in, interactions between basic research and industry. Public and private funding appears to always be lacking, and individual countries do not have the critical mass or the dimensions to implement large research infrastructures. There is therefore a real need to co-operate on a broad international level. Substantial research, development and demonstration (RD&D) of systems' conceptual/detailed designs are needed, as are other analyses. Refurbishment and/or construction of research infrastructure and facilities are increasingly complex and costly. By identifying the latest R&D needs and mapping infrastructure, opportunities exist to plan for the shared use of existing facilities and to undertake the development of others. The most important priorities are in the areas of the fuel cycle, fuel and materials irradiation, reactor safety, dedicated loops, mock-ups and test facilities, advanced simulation and validation tools, and transnational access to infrastructures, as well as the education and training (E&T) and knowledge management (KM) of scientists and engineers. GIF members strongly support a co-ordinated revitalization of nuclear RD&D infrastructures worldwide to a level that would once again help move forward in an accelerated manner a new generation of reactors.

Background/terms of reference

Background: At the 43rd GIF Policy Group (PG) meeting held on April 2017 in Paris, France, it was decided to establish the new GIF Task Force on R&D Infrastructure (RDTF). This task force accomplished its objectives over a short duration and took maximum benefit from the results through a dedicated workshop that was held in February 2020.

Objectives: Identify essential R&D experimental facilities needed for the development, demonstration and qualification of Gen-IV components and systems, including activities to meet safety and security objectives. To this end, the task force prepared relevant presentations and papers, and engaged with the private sector through a dedicated workshop. In the second phase, the task force promotes the utilization of the experimental facilities for collaborative R&D activities among GIF partners.

Organization: In 2019, the task force gathered and compiled from the six Gen-IV System Steering and provisional System Steering Committees their respective contributions in the area of infrastructures (existing infrastructure, needs and gaps). The year 2020 was focused on the second phase of this task force: "Promote the utilization of the experimental facilities for collaborative R&D activities among the GIF partners." To this end, existing mechanisms and approaches were identified, including organizational points of contact, to obtain access to relevant R&D facilities in GIF member countries. This information will then be made accessible to GIF participants and R&D organization, for example through the GIF website and the GIF members network. This action will promote closer NEA, GIF and IAEA international cooperation initiatives to stimulate joint funding from member countries and/or enterprises, as well as mutual benefits to be capitalized.

Main achievements in 2020

The completion of phase 1 and 2 of this task force led to two main actions in 2020/2021. Chronologically:

- Action no. 1: the GIF International Workshop with Nuclear Industry, which included SMR vendors and supply chain SMEs was organized successfully, with a total of 60 high-level participants, on 18-20 February 2020, at the NEA headquarters, in Boulogne-Billancourt, France. The first day and a half, the workshop was devoted to the topic of advanced manufacturing (see the AMME TF report in this chapter). The second half of the workshop was dedicated

Figure RDTF-1. GIF RDTF Workshop: "Views from the Private Sector, an Outlook for SMRs"

The discussion and questions session; from left to right: Dominique Hittner (USNC), Lou Martinez Sancho (CIO KAIROS Power), Stefano Monti (IAEA), Robin Manley (OPG), Richard Wain (Rolls Royce), Arkady Karneev (Rosatom), Frederik Vitabäck (GE-Hitachi), David Leblanc (Terrestrial Energy).

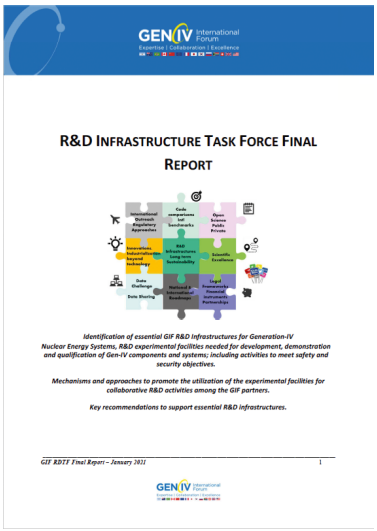

Figure RDTF-2. Cover page of the RDTF final report

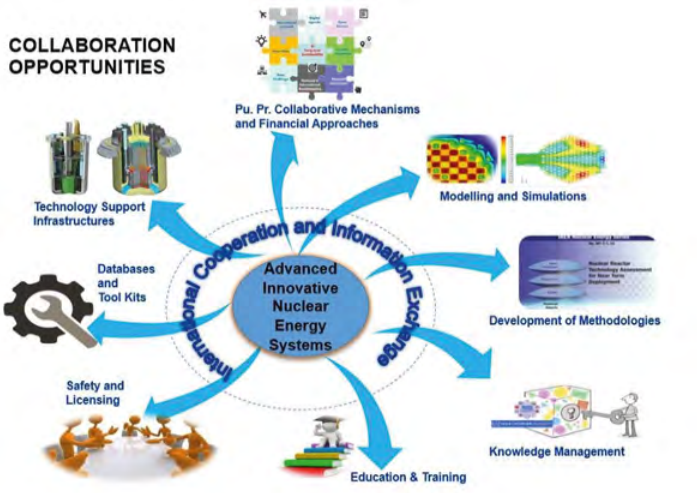

Figure RDTF-3. The virtuous wheel of international cooperation

to R&D infrastructure needs and opportunities. It included a review of RDTF efforts by system and roundtables with the private sector. The aim was: 1) to identify collaboration opportunities between private and public sectors for Gen-IV systems; 2) to ensure a networking event, gathering both GIF representatives and industry to create links; 3) to present concrete examples of collaboration between governmental organizations and industry; and 4) to gather views from the private sector on how to expand the relationship between GIF and the private sector in this field. The workshop was video recorded and can be seen on the GIF website (www.gen-4.org/gif/jcms/c_82829/workshops).

- Action no. 2: A dedicated GIF RDTF final report was presented at the GIF EG/PG meeting in Weihai (China, October 2019) for complete validation in 2020 from the Experts Group and the Policy Group. The report was finalized in early 2021 and uploaded to the GIF website. This final report is made up of 12 chapters that can be read independently, including an overview of R&D infrastructures for the six systems, along with cross-cutting R&D infrastructures, mechanisms and approaches for collaboration and key recommendations and conclusions.

The report thus provides a clear overview of R&D infrastructure for the six systems, as well as a cross-cutting approach. Chapters 10 and 11 offer an explanation of mechanisms and approaches for collaborative R&D activities (with examples in the appendix) and some recommendations to enhance or facilitate these activities.

It is stipulated in the report that because of its position within the relevant bodies of all member countries, and its close relationship with key influential nuclear institutions, GIF should play a proactive role in ensuring the optimization of available experimental platforms, as well as their sustainable use over the longer term. This can be carried out effectively by:

- promoting regular meetings to update relevant catalogues, compendium or databases of installations (i.e. at least once every two years);
- recalling that this subject is essential when preparing future international symposia and seminars;
- acting as the driving force for proposals within the framework of international initiatives, which could promote experimental infrastructures or enable the creation of new shared tools.

These two materials (i.e. the workshop record and final report) should be considered as a real springboard for enhancement of R&D facility use in future.

Conclusions (and/or next steps)

The missions assigned to this task force have been successfully fulfilled. As such, it is not considered relevant to further pursue the actions of this task force, as stipulated in the RDTF terms of reference. In accordance with the key recommendations given above, and the position of the GIF Policy Group in this regard, it will be necessary to determine how these initiatives will be articulated and should evolve in future

Taking into account the analyses and recommendations made by RDTF members, as well as private sector feedback from the workshop in February 2020, it would be preferable to seek for a new dedicated task force emerging from the conclusions of this RDTF report. Moreover, following all the recommendations set out above, it is necessary to highlight two topics largely put forward during the RDTF workshop. They are the sharing of:

- verification/validation and uncertainty quantification (VV&UQ) approaches and best practices between the different member countries;
- reflections on how to improve exchanges with regulators, at an early stage, to simplify and enable faster licensing processes for innovative systems, for example SMRs.

These two items could be the starting point for new GIF task forces that would be considered a logical continuation of the RDTF Task Force.

Roger Garbil
Chair of the RDTF, with contributions from RDTF members